Solving the M-Dwarf Luminosity Problem

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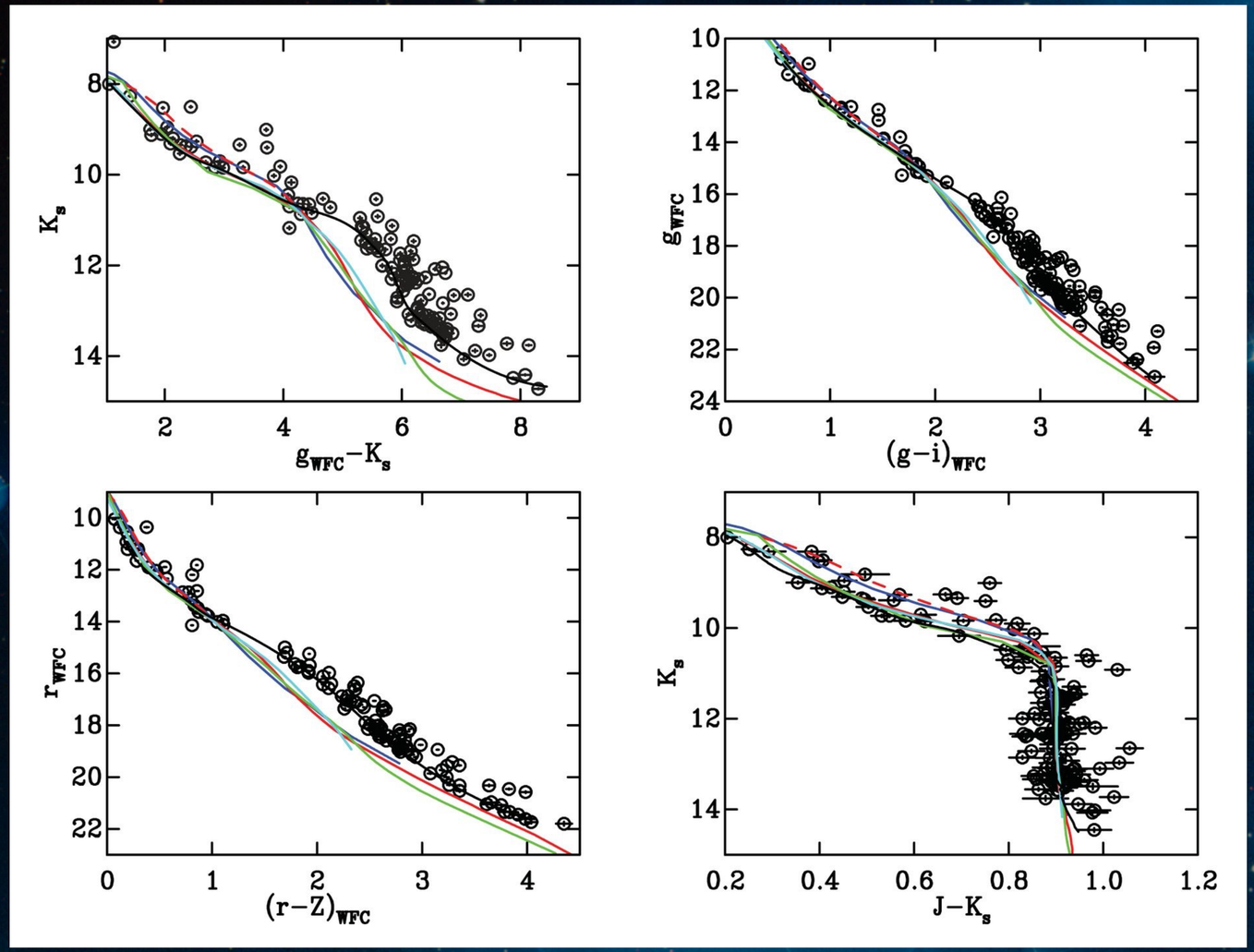
Image Credit: NASA, ESA and AURA/Caltech

Aims of the Project

- Reconcile fluxes from stellar models with observations of cool M-dwarf stars.
- Improve the accuracy of stellar ages for young M-dwarfs; allowing timescales to be improved for star and planet formation.
- Improve inputs to climate models of hosted exoplanets, which helps us determine if a planet is likely to be habitable.

Image Credit: NASA, ESA and AURA/Caltech

The M-Dwarf Luminosity Problem



- For effective temperatures $\lesssim$ 4000 K, M-dwarf models overestimate flux by a factor of 2 at 0.5 μm, with the difference decreasing at longer wavelengths.
- The discrepancy in the models means, depending on colour choice, ages can be underestimated by a factor of 2-3 for clusters younger than 10 Myr.

Cameron P. M. Bell et al. MNRAS 2012;424:3178-3191, Naylor (2009)

Image Credit: NASA, ESA and AURA/Caltech

Potential Causes

- Methods of dealing with convection in M stars have deficiencies, which are being actively investigated.
- Strong magnetic fields in low-mass stars is thought to lead to radius inflation, and hence cooler temperatures. (Feiden & Charboyer 2012)
- Temperature gradients in stellar atmospheres, which can be compensated for by tweaking the T-τ relation, as in Chen et al. 2012.

Image Credit: NASA, ESA and AURA/Caltech

Stellar Magnetism

- It's thought that strong shear from the tachocline in solar-like stars is responsible for strong magnetic fields.
- This would suggest that low-mass, fully convective stars would have weak magnetic fields, if any.
- However, we see equally strong magnetic fields in fully convective stars, suggesting an alternate mechanism.

Image Credit: NASA, ESA and AURA/Caltech

Why Should I Care!?

Image Credit: NASA, ESA and AURA/Caltech

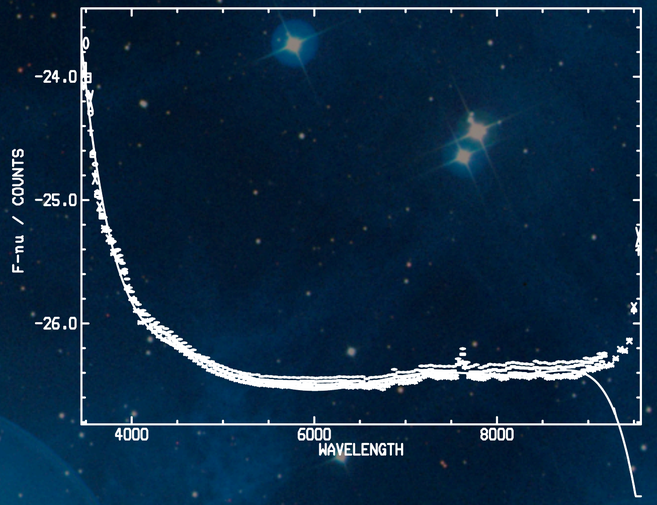
Stellar Ages

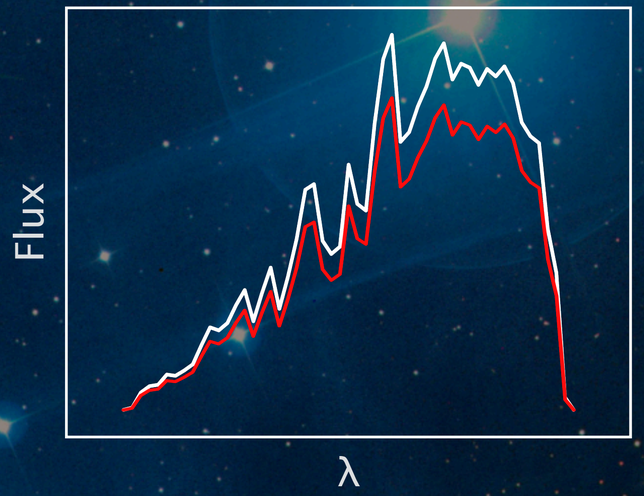
- There are many methods for the determination of stellar ages, both in the MS and the PMS. Many are affected by issues with low-mass stars. These include:
  - Isochrone Fitting on CMDs
  - Lithium Depletion
  - Gyrochronology

Image Credit: NASA, ESA and AURA/Caltech

Our Solution

WHT – Image Credit: RGO





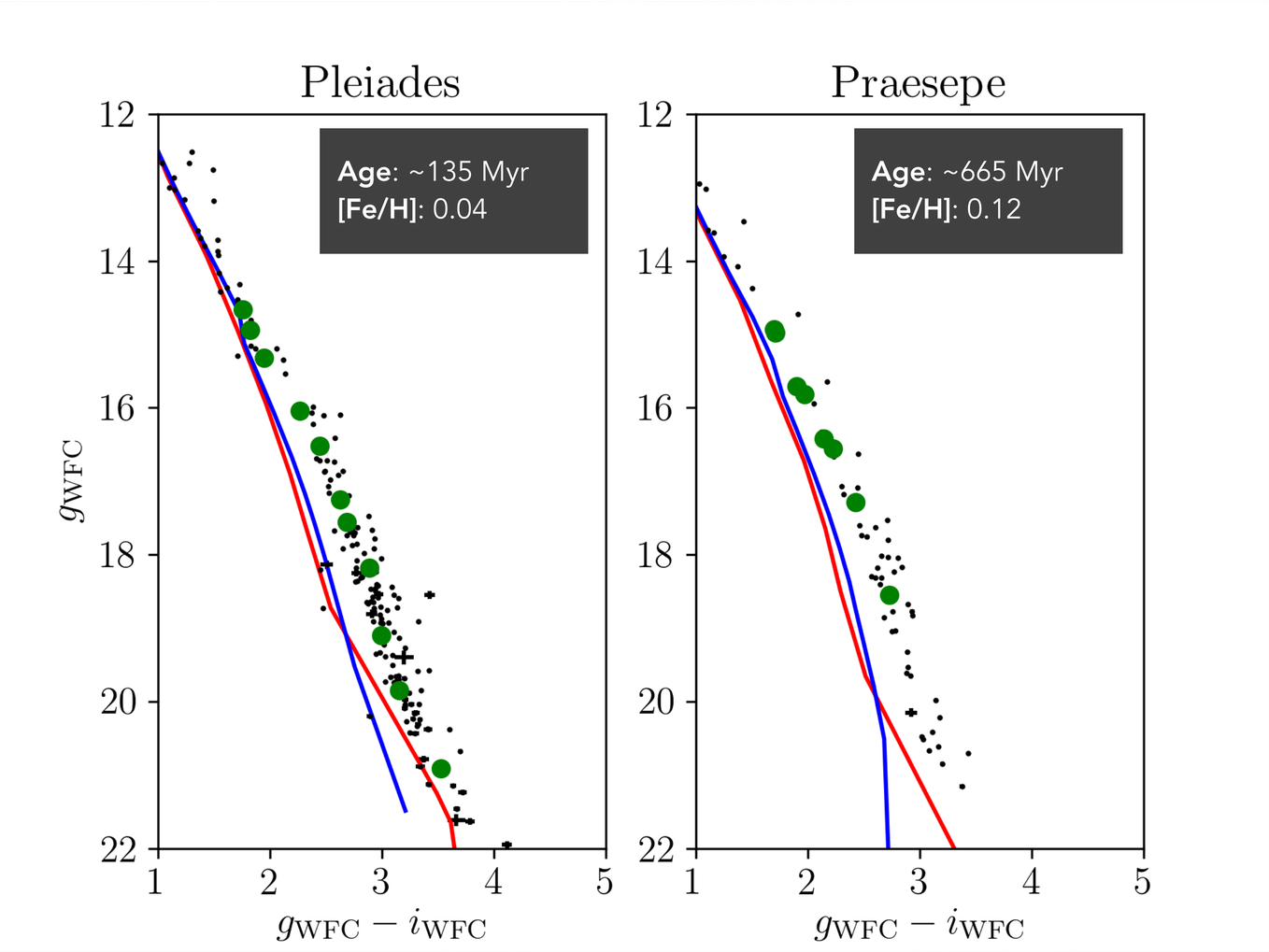
Observe Spectra

Process and Flux Calibrate

Compare to Models

Image Credit: NASA, ESA and AURA/Caltech

Target Selection



- Plotted are the Baraffe et al. (2015) (red) and Dotter et al. (2008) isochrones. The black points are photometry and the green points are our targets.
- They are chosen to span the parameter space in which the discrepancy exists.

Soderblom et al. 2009; Brandt et al. 2015; Bell et al. 2014; Rees et al. (in prep); Baraffe et al. (2015); Dotter et al. (2008)

Image Credit: NASA, ESA and AURA/Caltech

Photometric Fitting

- We only have visible spectra, so we use our griz photometry along with data from UKIDSS, 2MASS, WISE and Spitzer IRAC to extend the fit.
- **Isochrone Fit**: A model fit limited to models that appear along the theoretical isochrone and placed at the appropriate distance for the cluster.
- **Free Temperature and Radius Fit**: A fit performed using models that span the entire feasible parameter space for our stars. This is normalisation independent, so we are not hampered by inaccurate distance or radius determinations.

Image Credit: NASA, ESA and AURA/Caltech

Photometric Fitting

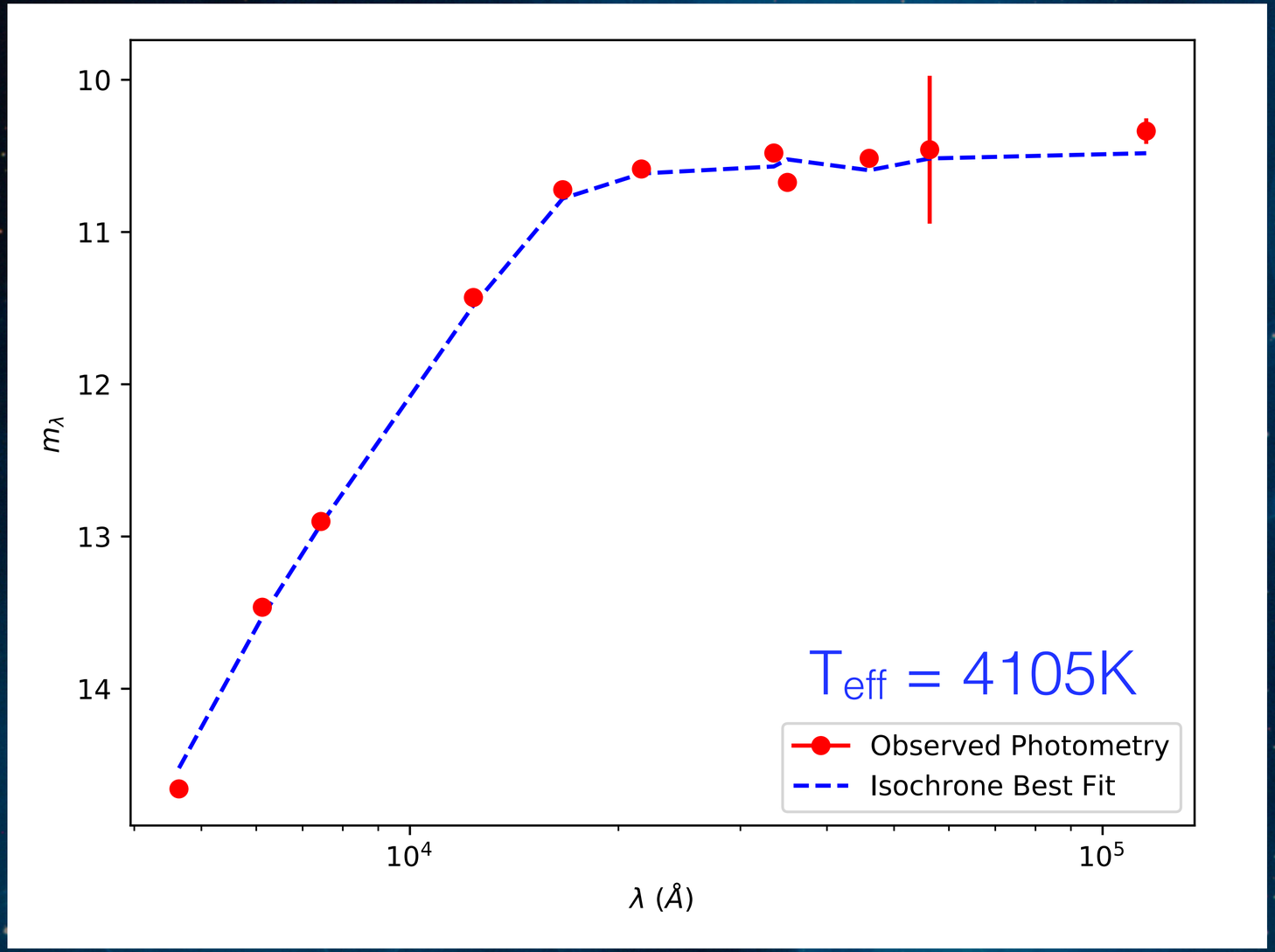


Image Credit: NASA, ESA and AURA/Caltech

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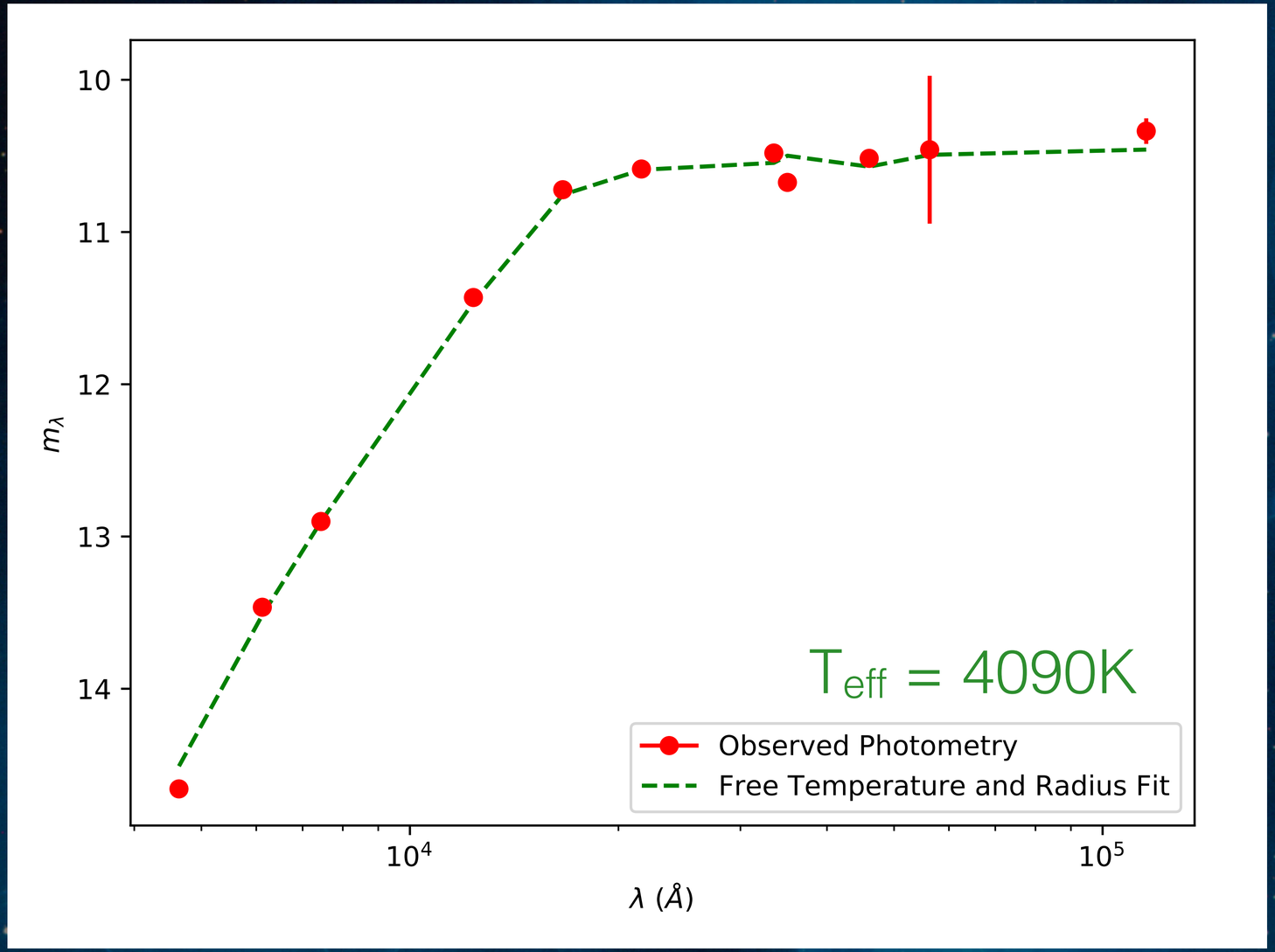

Image Credit: NASA, ESA and AURA/Caltech

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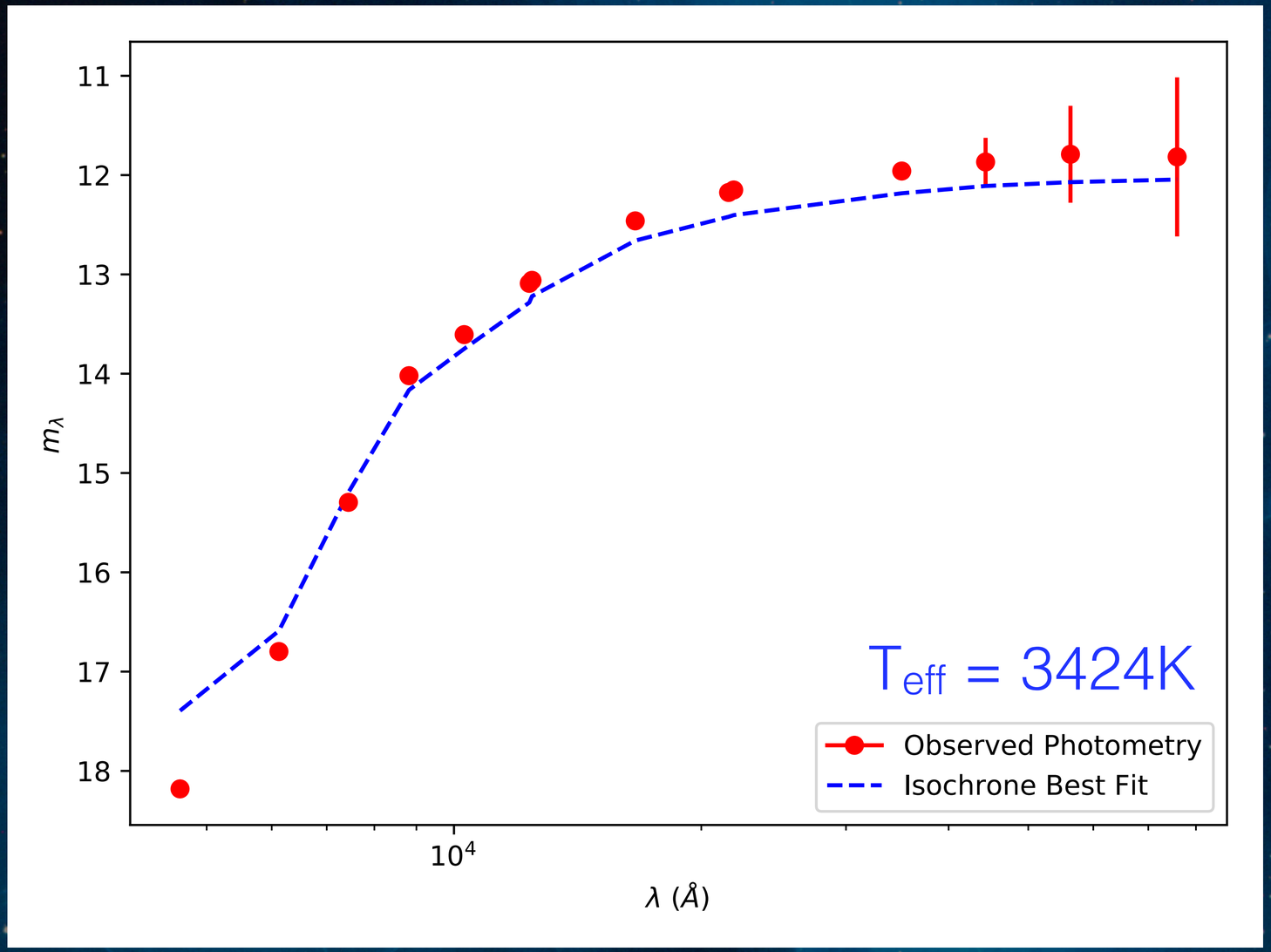


Image Credit: NASA, ESA and AURA/Caltech

Photometric Fitting

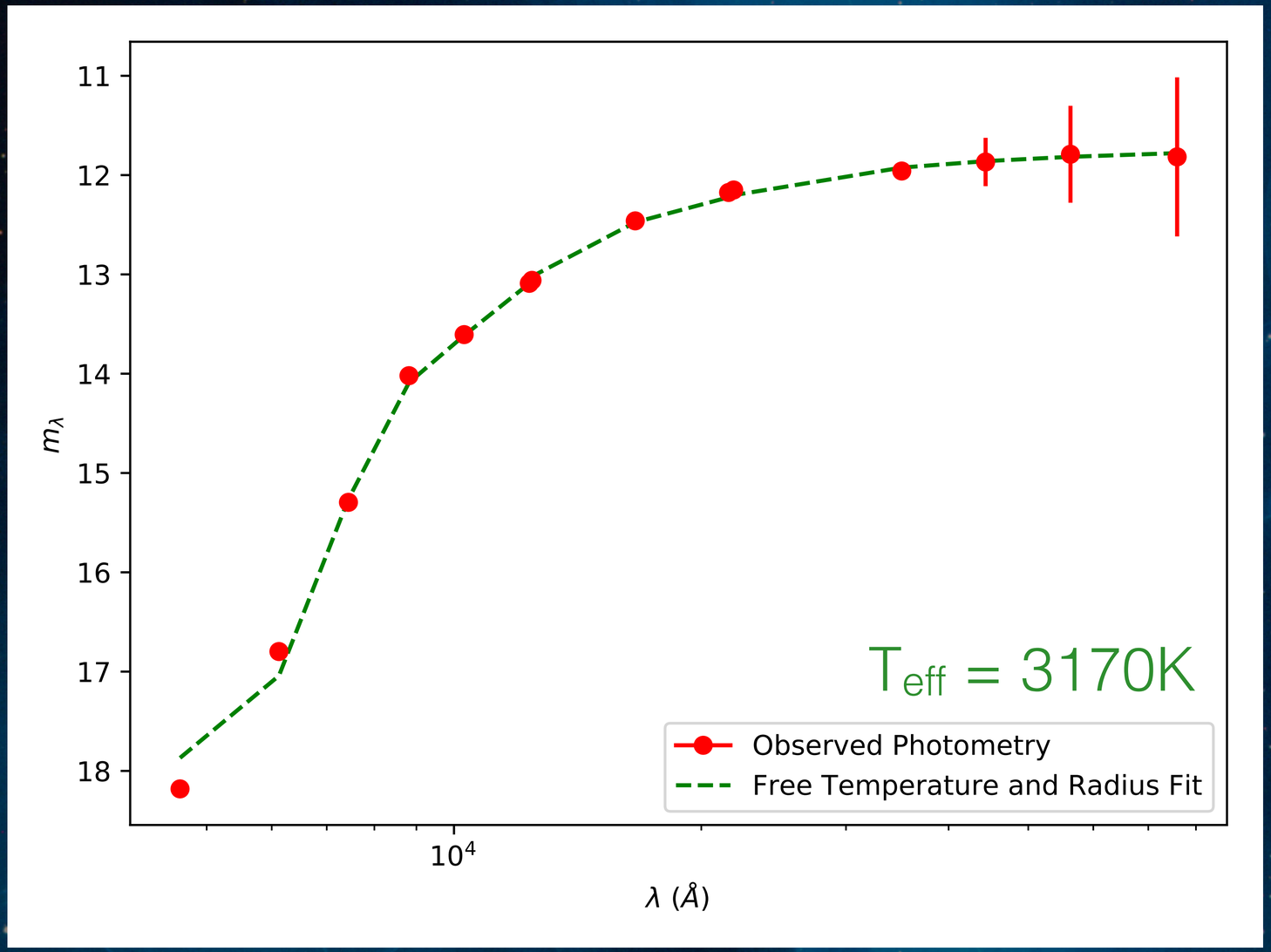
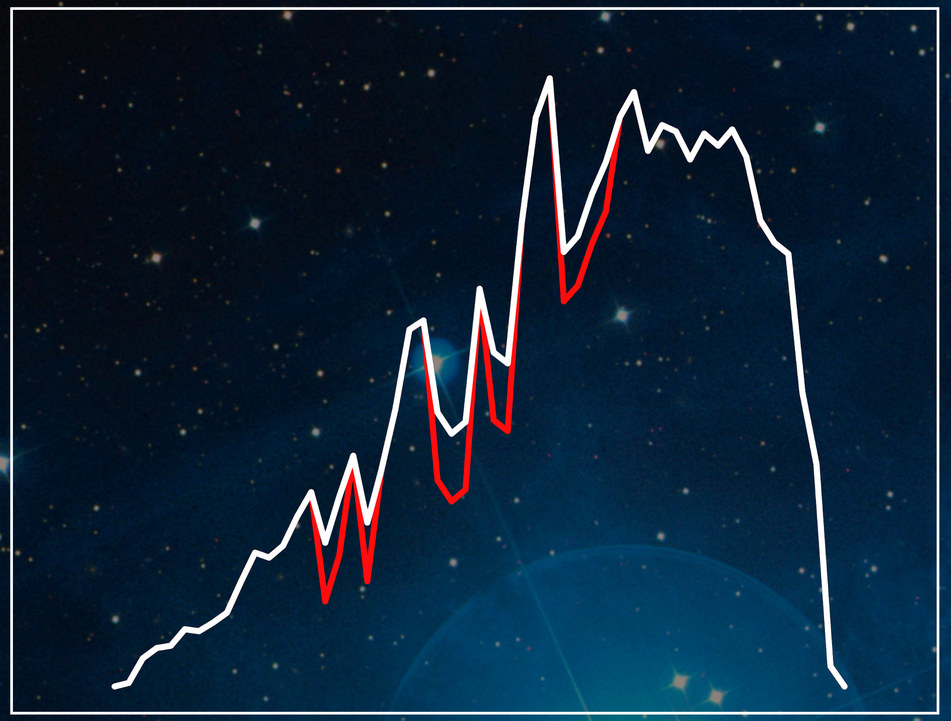


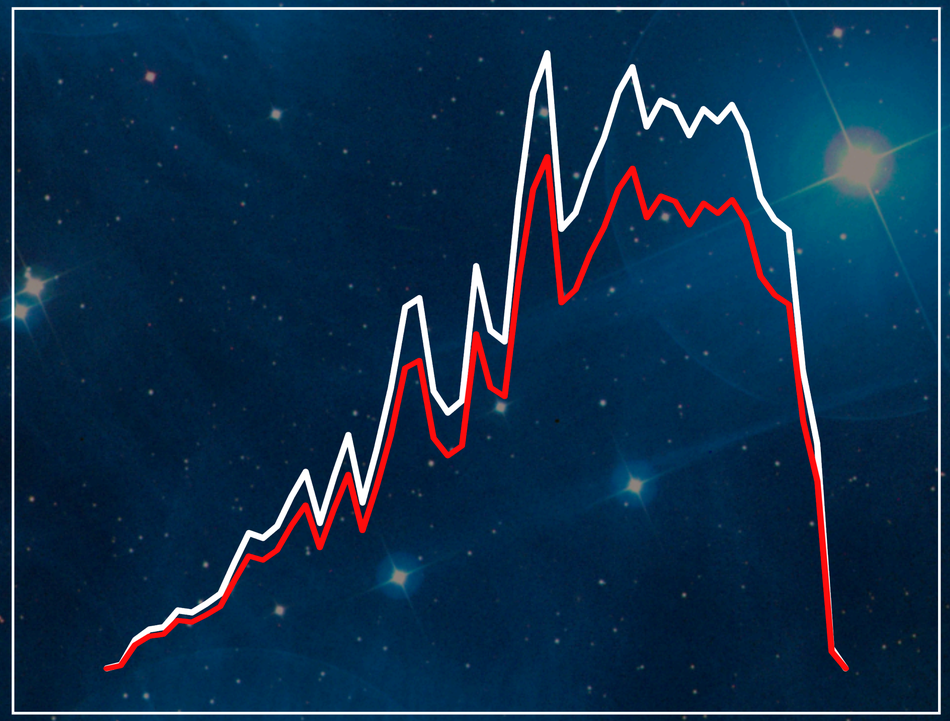
Image Credit: NASA, ESA and AURA/Caltech

Spectral Index Fitting



LOCALISED OPACITY

- AND -



NEARLY-GREY OPACITY
RADIUS INFLATION

Beeck et al. 2013; Allard et al. 1992;

Image Credit: NASA, ESA and AURA/Caltech

Fluxed Spectra

- We have produced a collection of robustly flux-calibrated M-dwarf stars from the Pleiades and Praesepe.
- We are directly comparing them to Baraffe et al. (2015) stellar models.
- As suggested, there is a nearly-grey absorption, increasing with decreasing temperature, with decreased opacity localised around spectral lines.

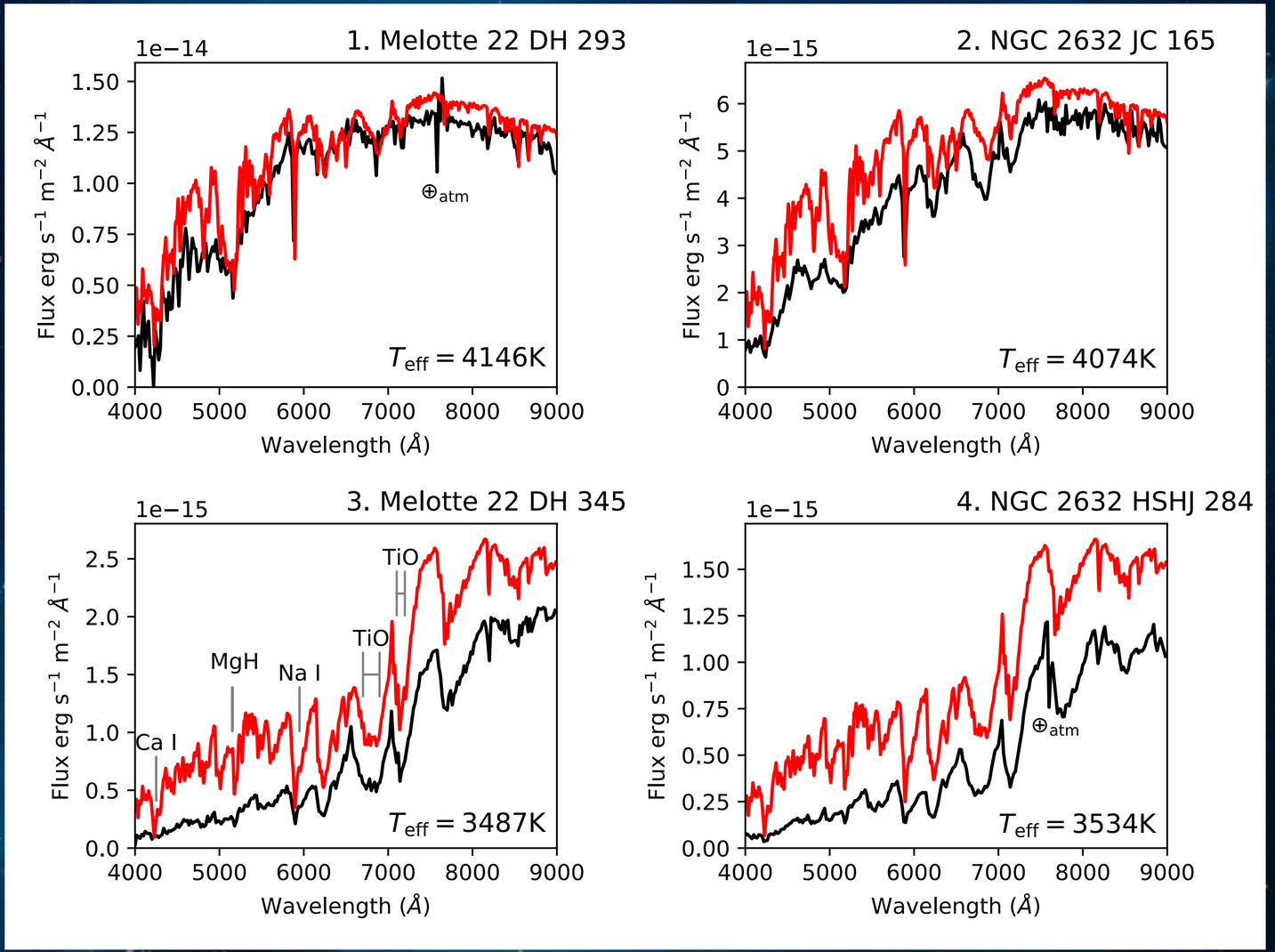


Image Credit: NASA, ESA and AURA/Caltech

Conclusions

- Using robustly flux calibrated M-dwarf spectra, we aim to find out why models over predict M-dwarf fluxes at optical wavelengths.
- Doing this will improve the accuracy of ages, planet formation timescales and inputs to exoplanet climatology.
- Preliminary analysis suggests a 5-10% inflation in radius, which is strongly supported by observations of DEBs.

Thank you for listening

Any questions?

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